SPATIAL ANALYSIS AND ENVIRONMENTAL FACTORS ASSOCIATED AGAINST CASE OF DENGUE HEMORRHAGIC FEVER (DHF) IN LIMBOTO DISTRICT, GORONTALO

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Abstract

Dengue Hemorrhagic Fever (DHF**)** was a disease caused by dengue virus. DHF transmitted by mosquito bites from *Aedes* genus, mainly *Aedes aegypti* and *Aedes albopictus*. DHF was emerging over the year and attacking all of age groups. It was related to the environmental condition and community behavior. Until now, the Incidence Rate (IR) of DHF from 1968 was increased. Mortality caused by DHF was categorized as high if CFR more than 2%. Therefore, there were 5 provinces that categorized on high CFR in 2014 such as Bengkulu, Bangka Belitung Archipelago, South Borneo, Gorontalo and Maluku. Gorontalo Province consisted of 5 regencies and Gorontalo Regencies increased dengue cases significantly, especially Limboto District i.e., 35 cases in 2012, 49 cases in 2013, 34 cases in 2014, and 40 cases by 2015 by 8 endemic counties. Objective of this study was to understand spatial distribution of DHF cases and analysis environment factor against cases of DHF in Limboto District. The method of study was observational used cross sectional study design supported by Geographic Information System (GIS) for spatial information. Main result by Poisson's regression test showed that the environmental variables for instance precipitation, temperature, humidity, and wind speed with DHF occurrence. Correlation analysis of environmental variables to DHF cases showed that only the humidity in the previous two months (lag2) (P = 0.01) had a significant but negative correlation with DHF cases.

Keyword: DHF cases, Precipitation, Temperature, Humidity, Wind Speed

INTRODUCTION

Dengue Hemorrhagic Fever (DHF) has become public health problem over the last 45 years since 1968 until now and it has spread in 33 provinces and 436 districts of 497 districts (88%). Mortality caused DHF is categorized as high if CFR more than 2%. Therefore, there were 5 provinces that categorized on high CFR in 2014 such as Bengkulu, Bangka Belitung Archipelago, South Borneo, Gorontalo and Maluku. Those provinces need to sought improvement of healthcare quality, quantity and quality of health workers in hospitals and Public Health Center (PHC) included improving the supporting tools of diagnostic and management for patients in healthcare facilities.[1]

DHF in Gorontalo District has become endemic diseases every year and reported deaths of patient. DHF in Gorontalo has been categorized on vigilant level. Case of DHF has declared as extraordinary circumstances.[2] Over January until Desember 2014 was reported amounts 269 cases of DHF in Gorontalo. 13 persons of DHF's patients were died. Case of DHF in Gorontalo showed the improvement significantly, especially on Limboto as the government center of Gorontalo.[2]

Limboto District is the highest district for dengue fever cases in 107 cases in 2010, 1 case in 2011, 35 cases in 2012, 49 cases in 2013, 34 cases in 2014, and 40 cases in 2015 and in Limboto District is founded in 8 endemic villages of Bolihuangga, Bongohulawa, Hepuhulawa, Hunggaluwa, Hutuo, Kayu Merah, Kayu Bulan and Tenilo. Various efforts have been made by Health department of Gorontalo in overcoming DHF, but DHF case still remains high and difficult to be controlled.[2]

According to Rosli et al (2010), spatial analysis is used to detect and gauge pattern the disease which can give the purpose of epidemiology disease.[3]
In the analysis spatial, there are three steps which determine auto spatial correlation occurring in space unit, determine the occurrences of a disease, and make mapping disease. The distribution of

dengue fever case is expected to increase information to identify which one have high risk the case.[4] It is not yet known patterns of spatial detail regarding DHF cases in the of Gorontalo District, especially the Limboto District so this study is conducted to analyze the spatial case of DHF in terms of physical environmental factors.

RESEARCH METHODS

a. Type and Research Design

Type of study was observational used cross sectional study design supported by Geographic Information System (GIS) to collect spatial information. Research design was a study of ecological with an approach spatial-temporal. The independent variables in this study were the environments. They were precipitation, temperature, humidity and wind speed while the dependent variable in this study was the case of DHF. Population in this study was all cases in the administrative area of Limboto District with the case of DHF during the period of 2012-2015.

b. Study Area

Limboto district was one of 19 Districts on Gorontalo Regency. This district consisted of 12 villages. Total area of Limboto District was 130.5 km^2 or equal to 5.91% total area of Gorontalo Regency. The widest village was Polohungo and seen of earth surface morphology, most areas in the form are lowland region.

Borderline of Limboto District, the east by District of Telaga Biru, the west by District of Limboto Barat, north borders with Gorontalo Utara Region and south by the District of Tabongo and Lake Limboto.

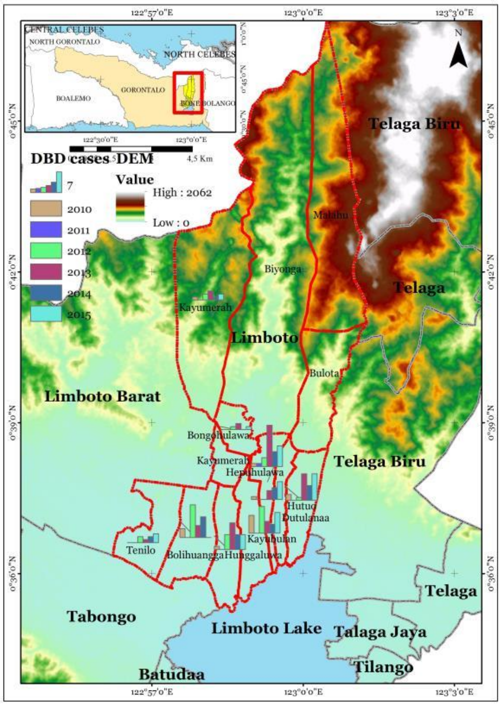

Figure 1.Study Area (Limboto District) and DHF Case 2012-2015

c. Data Collection

In order to achieve the objective of this study, several data were required to be incorporated in GIS environment such as DHF case data and precipitation data and climatology data. These data were gathered from various sources.

d. Data Analysis

1. Univariate Analysis
   Univariate analysis was statistically used to know the frequency distribution of each variable in this research that was environmental factor (precipitation, temperature, humidity and wind speed) and DHF cases in Limboto District.
2. Graph/Time-Trend Analysis
   Graph/time-trend analysis was performed to show the pattern of graphic relationship among the environmental variables (precipitation, temperature, humidity and wind speed) on DHF cases.
3. Bivariate Analysis
   Bivariate analysis was performed to see the statistically correlation between environmental variables

with DHF cases. Before performing bivariate data analysis, it was necessary to test the data normality. If the data was normally distributed, the test was Pearson Moment correlation test, and if the data was not normally distributed then the test to be used was Spearman-Rho correlation test. The correlation test was performed by linking the occurrence of DHF with environmental variables (precipitation, temperature, humidity and wind speed) in the same month (lag0) up to two previous months (lag2). According Dahlan (2010) Interpretation of correlation power between two variables based on their correlation coefficient value could be divided into five.[5]

r = 0-0.2 extremely weak
r = >0.2 – 0.4 weak
r = >0.4 – 0.6
medium r = >0.6
– 0.8 strong
r = >0.8 extremely strong

4. Multivariate Analysis
Multivariate analysis was conducted to show
the influence on environmental variables (precipitation, temperature, humidity and wind speed) with DHF cases. This analysis was done by using *Poisson Regression*. If there was an assumption violation, the analysis proceeded with a *Negative Binomial Regression*. This research thus got the best regression model.
The Poisson Regression Model could b e generally written as follows:

$$In(Y) = \beta_0 + \beta_1 Xi_1 + \beta_2 Xi_2 + ... + \beta_k Xi_k$$
$$Y = exp (\beta_0 + \beta_1 Xi_1 + \beta_4 Xi_4 + ... + \beta_k Xi_k)$$

5. Spatial
Analysis
The data was presented in thematic maps illustrating the distribution of cases in 12 villages in the district administrative Limboto District. Meanwhile, to create thematic maps environment variable interpolation advance. Interpolation was executed by using environmental variable data in the form of point from weather station, so it became data area (surface) such as precipitation, temperature, humidity and wind speed. Then, to show the pattern of the relationship on independent variables and the dependent variable spatially, overlaying thematic maps the distribution of DHF cases with environmental variables.

RESULTS

Precipitation and climatological data collected through the Central River Region of Celebes II. In the study area, there were 21 precipitation gauge stations distributed inside or outside the study area, but in this study only affected 2 precipitation gauge stations due and 1 climatology stations. The data collected as the variables studied in this study were precipitation, temperature, humidity, and wind speed for 4 years (2012-2015).

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1. Univariate
Analysis

Univariate analysis data showed frequency distribution of environment variables and DHF cases in Limboto District in 2012-2015. The characteristics of each research variable descriptively presented in Table 1.

Table 1. Frequency Distribution of Environment Variables

Variables	X	Var	SD	Max	Min
Precipitation	141.179	7800.817	88.322	333	1.7
Temperature	27.107	0.181	0.425	28.19	26.2
Humidity	83.211	17.306	4.160	91.26	67.39
Wind speed	108.714	2298.945	47.947	246.18	49.18
DHF cases	3.229	22.818	4.777	26	0

Monthly precipitation in Limboto District during 2012-2015 showed a maximum value of 333 mm occurred in April 2013. Minimum value of 1.7 mm occurred in September 2014. The monthly temperature in the period 2012-2015 was not too varied. The maximum value of 28.19^{o}C occurred in December 2015, and the minimum value of 26.20^{o}C occurred in July 2013. Humidity during the period 2012-2015 showed the maximum value of 91.26% occurred in September 2013 and the minimum value of 67.39% in December 2015. Wind speed for the 2012-2015 period showed a maximum value of 246.18 km / day occurred in August 2015 and a minimum value of 49.18 km / day in May 2013.

The test results showed the monthly precipitation and monthly temperature variables had p> a (0.05), meaning Ho was accepted, so that they did not have normal curve or normal data variables and the humidity, wind speed and DHF cases were non-normal distribution (Table 2).

1. Bivariat Analysis

Table 2. Data Normality Test Results

Variabel	*Shapiro-Wilk*	Normality
Monthly Precipitation	0.14365	Normal
Monthly Temperature	0.43425	Normal
Monthly Humidity	0.00002	Non-Normal
Monthly Wind speed	0.00107	Non-Normal
Monthly DHF cases	0.00000	Non-Normal

Table 3. Correlation Analysis Of Environmental Variables Against Dengue Event Monthly

Lag	Precipitation		Temperature		Humidity		Wind Speed	
	p-value	r	p-value	r	p-value	r	p-value	r
0	0.0820	0.2536	0.9982	-0.0003	0.9205	0.0148	0.9854	-0.0027
1	0.9964	0.0007	0.8861	-0.0212	0.846	-0.1948	0.9994	0.0001
2	0.2269	0.1776	0.8290	0.0320	0.0132	-0.3554	0.8693	0.0244

Table 3 showed only the humidity in the previous two months (lag2) P = 0.01 which had a significant relationship but the correlation was negative. Negative correlation meant if the humidity increased 1%, it would decrease one case of dengue.

2. Time-Trend Graph Analysis

Time-series graph of monthly precipitation with DHF cases showed the it tended to be directly proportional that the case of DHF cases increased when precipitation increased and vice versa, except the month with high precipitation that was > 250 mm (May 2013), it tended to decrease the number of DHF cases (Figure 2). On the graph of monthly temperature and DHF cases showed a tendency to be proportional to the case of DHF increased when the monthly temperature increased and vice versa (Figure 2). On the graph of monthly humidity and DHF cases each year tended to be directly proportional to 2012-2014 and it was inversely proportional to 2015 (Figure 2). Graph of wind speed and DHF cases showed the case of DHF mostly occured when the wind speeds range were from 35-100 km/day (figure 2).

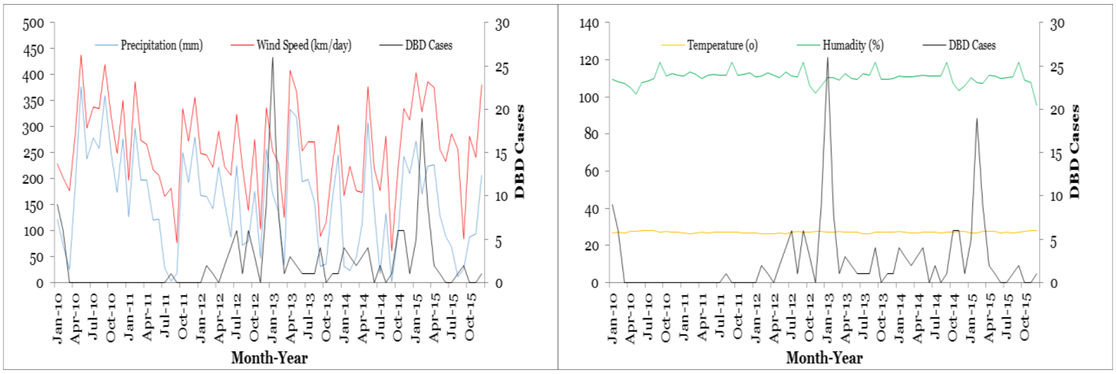

Figure 2. Time-Trend Graph among Precipitation, climatology variable and DHF Case

3. Spatial Analysis

The result of overlay of the thematic annual precipitation and annual DHF cases map did not all have a directly proportional relationship spatially. In general, in 2012-2015, region in high areas and high precipitation, but DHF case was very small or no DHF cases. It explained that the elevation factor of the region was quite influential on the case of DHF in Limboto District. Limboto District was an endemic area due to every year contained DHF cases, although high annual precipitation in the north and low in the south areas.

The result of the overlay between the annual temperature and annual DHF cases map showed that there was a spatial unidirectional relationship in the eastern area of Limboto District every year that was the high DHF occurrence when in the region having temperature 26oC-27,5oC which it was the optimum temperature for growth and physiological processes of mosquitoes.

Humidity could affect the lifespan of mosquitoes so that the effect was also the chance to be a vector of disease. When overlaid between the annual humidity map and the occurrence of dengue fever, it was seen that there was a spatial inversely proportional relationship with humidity in Limboto District in the last four years from 2012 to 2015 that was greater than 80%. This caused the number of cases of DHF in some districts was not significant.

On the map of annual wind speed in Gorontalo regency in the last four years from 2012-2015, it was seen that the central and eastern regions of Limboto District had high wind speeds. The wind affected the flying distance of mosquitoes and the pattern of the spread of mosquitoes. Seen on the overlay map of wind speed and DHF cases, the high wind speed fluctuation pattern that could be seen from color degradation on the map, would be followed by the high DHF case in the region and vice versa.

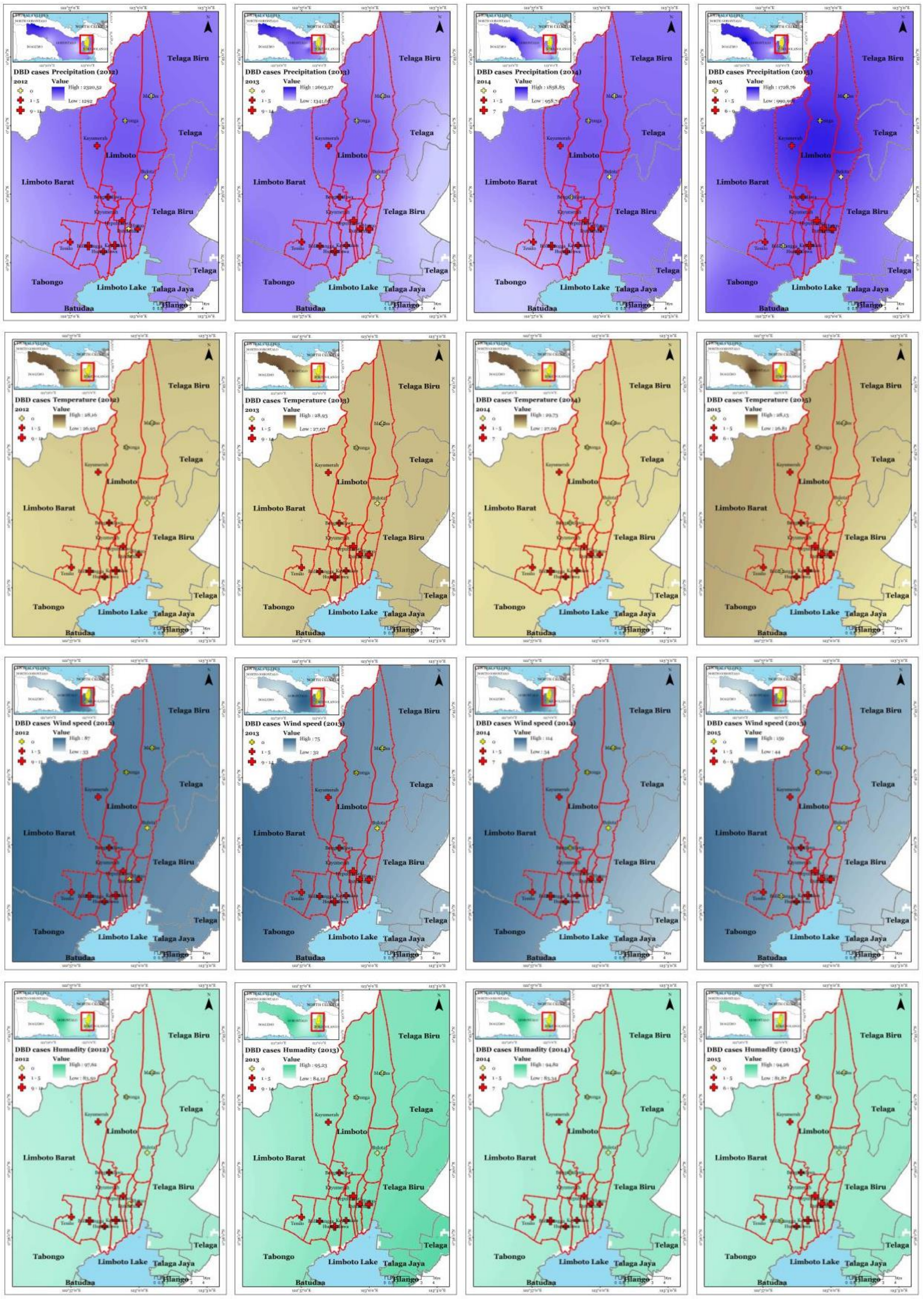

Figure 3. Map Of Distribution Precipitation, Climatology and DBD Cases: Precipitation; Temperature: Wind Speed; and Humidity (Top to Down)

4. Multivariat Analysis

Regression analysis involved several predictor variables (independent) there was non- multicolinearity requirement that must be met where the predictor variable in the model must be independent or not correlated each other, in this research multicolinearity test was based on the correlation value (<0.95) and *Varian Infloating Factor* (VIF<10).

Table 4. Result of Independent Multicollinearity Test

Variabel	R	r^2	*Tolerance* ($1-r^2$)	VIF (1/TOL)
Monthly Precipitation- Monthly Temperature	0.00	0.00	0.99	1.00
Monthly Precipitation - Monthly Humidity	-0.24	0.05	0.94	1.06
Monthly Precipitation – Monthly Wind Speed	-0.17	0.03	0.96	1.03
Monthly Temperature - Monthly Humidity	-0.49	0.24	0.75	1.33
Monthly Temperature - Monthly Wind Speed	0.07	0.00	0.99	1.00
Monthly Humidity - Monthly Wind Speed	-0.27	0.07	0.99	1.08

a. Poisson regression analysis

Variables used into the Poisson Regression analysis described in Table 5. The Poisson Regression Model could be generally written as follows:

$In(Y) = \beta_0 + \beta_1 Xi_1 + \beta_2 Xi_2 + \dots\dots\dots + \beta_k Xi_k$ (1)

$Y = \exp(\beta_0 + \beta_1 Xi_1 + \beta_4 Xi_4 + \dots\dots\dots + \beta_k Xi_k)$ (2)

From the results of Table 6, the Poisson Regression Model was generated as follows: $In(Y) = 24.597 + 0.023X_1 + 0.565X_5 - 0.680X_6 - 0.235X_{10} - 0.007X_{13}$

Table 5. Variable Poisson Regression Analysis

Variable	Information
Y	monthly DHF
X_1	monthly DHF cases in the previous month (*lag1*)
X_2	monthly precipitation in the same month (*lag0*)
X_3	monthly precipitation in the previous month (*lag1*)
X_4	monthly precipitation in the previous two months
X_5	(*lag2*) monthly temperature in the same month (*lag0*)
X_6	monthly temperature in the previous month (*lag1*)
X_7	monthly temperature in the previous two months
X_8	(*lag2*) monthly humidity in the same month (*Lag0*)
X_9	monthly humidity in the previous month *lag1*)
X_{10}	monthly humidity in the previous two months (*lag2*)
X_{11}	monthly wind speed in the same month (*lag0*)
X_{12}	monthly wind speed in the previous month (*lag1*)
X_{13}	monthly wind speed in the previous two months (*lag2*)

Table 6. Result of Regression Poisson Analysis

Parameter	Estimate	Standart Error	P Value	Information
β_0	24.597	8,578	0.004	constants
β_1	0.023	0.011	0,047	DHF cases in in the previous month (*lag1*)
β_5	0.565	0.260	0,030	monthly temperature in the same month (*lag0*
β_6	-0.680	0.267	0,011	monthly temperature in the previous month (*lag1*)
β_{10}	-0.235	0.312	0,000	monthly humidity in the previous two months (*lag2*)
β_{13}	-0.007	0.002	0.002	wind speed in the previous two months (*lag2*)
L_1	-110.950			
L_0	-164.95			

DISCUSSION

Based on the map of distribution DHF events from 2012 to 2015, the movement of dengue cases tended to attack the area which was closed to Lake Limboto. In the year 2012-2015, most cases of DHF were found in Limboto District.

The result of correlation statistic test between monthly precipitation and monthly DHF cases had positive correlation coefficient but it had no significant correlation. Precipitation could affect the life of mosquitoes in 2 ways, namely: causing the rise of air relative humidity and adding a place of longing. Every 1 mm precipitation added a density of 1 mosquito, but if the weekly precipitation was 140 mm, the larvae would drift and die.[6] This was in line with the research conducted by Iriani (2012) on the assessment of the relationship between monthly precipitation rates and dengue cases through Spearman correlation test ie there was a correlation between precipitation and increasing the number of dengue cases treated.[7] The correlation began one month before the peak precipitation ($r = 0.332$, $p = 0.001$), increased during peak precipitation ($r = 0.353$, $p = 0.000$), and weakened one month afterwards ($r = 0.262$; $p = 0.008$).

While for yearly graph analysis showed that the relationship of monthly precipitation and monthly DHF cases tended to be unidirectional. The highest annual precipitation was in 2010 and 2013 where in that year DHF cases were also very high, this proved that there was a relationship of annual precipitation with annual DHF cases. If it was observed on the overlay map between thematic annual precipitation maps and thematic maps of monthly DHF cases per county, where in 2012-2015 high annual precipitation occured in some areas of Limboto District located adjacent to Lake Limboto. The result of overlay of thematic annual precipitation maps and the annual DHF cases did not all have a directly proportional relationship spatially. In 2012-2015, county in high areas had high annual precipitation, but the annual DHF cases were very small or no DHF cases at all. This explained that the altitude of the place was enough to affect the case of DHF in Limboto District.

The results of research conducted by Chen et al (2012) using Correlation Person Product Moments obtained results that the extreme precipitation associated with the case of 8 infectious diseases in Taiwan during the period 2004-2008, including dengue fever disease. Precipitation was significantly associated with dengue fever with P value of test (0.0212).[8] The results of research by Thai et al (2010), with time series analysis of climate variables in all districts in Vietnam with DHF cases, it was found that climatic variables were significantly related to DHF cases over the last 2-3 years.[9] In a study conducted by González et al (2011) using multiple regression analysis, the rainy season, winter and dry season had an effect on increasing the DHF cases ($P = 0.079$, $P = 0.008$; $P = 0.015$) in Mexico.[10]

Temperature was one of the environmental factors that affected the breeding of *Aedes Aegepty* mosquito larvae and also affected the development of viruses in the mosquito body.[11] In this study there was a relationship between monthly temperature with the monthly DHF cases statistically and it would be stronger when associated with fluctuations in monthly temperature in the previous 2 months (lag2) was associated with the monthly DHF cases. In the correlation analysis of this study, there was no significant relationship between temperature with the DHF Cases statistically $P = 0.9982$.

The research was in line with Dini et al. research, which stated there was no relation between temperature and DHF case in Serang Regency in 2007-2008.[12] However, this study was not in line with the results of research conducted by Thai, with the result that the climate variable (temperature) was significantly related to DHF cases over the past 2-3 years.[9] This could be due to differences in total duration of data taken in conducting research and difference in conditions where conducted the research. Increased temperature due to climate change caused the incubation period of mosquitoes was getting shorter. The impact of mosquitoes would multiply faster. Increasing the population of mosquito vectors would increase the chances of disease agents with mosquito vectors (such as dengue hemorrhagic fever, malaria, filariasis, chikungunya) to infect humans.[13]

The results of research by Costa et al (2010) on the impact of temperature and humidity variation on reproduction activities and survival of Aedes aegypti mosquitoes, the results obtained that at 35°C and relative humidity of 60% would decrease the level of mosquito oviposition (average 54,53 ± 4.81 eggs), whereas at 25oC and relative humidity
80%, the potential for mosquito oviposition rate
(mean 99.08 ± 3.56
eggs).[14]

In this study, the fluctuation of monthly humidity in the same month (lag0) showed positive correlation coefficient value but statistically in significant value was associated with monthly DHF case. However, different things were shown in the monthly humidity of the previous 2 months (lag2) that the negative correlation coefficient value was negative (r = -0.355) but had significant value (p = 0.01) associated with monthly DHF cases. According Dini (2010), humidity did not directly affect the case rate of DHF, but it affected the age of *A. Aegypti* mosquito which was the vector of dengue transmitter. Mosquito breathed by a tracheal pipe with an aperture which was called spiracle.[12] Spiracles that were open without a regulatory mechanism at low humidity would cause evaporation of water from inside the mosquito body so that the mosquito's body fluid would come out. In addition, the need for high humidity caused mosquitoes to find a humid and wet place outside the home as a place to rest during the day.[15]

In the time-series graph the monthly humidity relationship and monthly DHF cases tended to be reversed was the monthly DHF cases increased when the monthly humidity decreased. The same thing was also seen on the overlay map between annual humidity and the annual DHF cases that there was a relationship inversely spatially over the last four years 2012-2015. According to Sukamto (2007), *Aedes aegypti* mosquitoes would lay their eggs at an air temperature of about 25°-30°C. Eggs laid in water would hatch at 75 hours or 3 to 4, but at temperatures less than 17°C could only last for 1 hour.[16] According to Gubler (2010), air humidity affected the age of mosquitoes. At temperature 20oC relative humidity 27% age 31 day female mosquitoes and age 35 days male mosquito, relative humidity 55% age 88 day female mosquitoes and male mosquito 50 days.[17] At relative humidity less than 60% of the age of the mosquito would be short, it could not be a vector, because there was not enough time to transfer the virus from the stomach to the salivary glands. Therefore, more than 60% of the air humidity made *Aedes aegypti* mosquitoes long and potential for breeding of *Aedes aegypti* mosquitoes.

Monthly wind speed had a strength of correlation value which was weak with a positive direction when associated with previous months (lag) but there was no significant relationship with the monthly DHF cases. This was in line with the research of Wiragoya (2013) that the statistical results between wind speed with the case of DHF showed the value of r= 0.057 and p = 0.632 which meant that wind speed had a very weak relationship strength and there was no significant relationship between wind speed and the case of DHF.[13] On the graph between monthly wind speed and monthly DHF cases each year showed a direct relationship for the year 2012-2015. Seen on the map of annual wind speed overlaid with annual DHF cases, the pattern of high annual wind speed fluctuations that could be seen from the degradation of color on the map, it would be followed by the high annual DHF cases in the region and vice versa.

In Lu et al (2009) it was explained that the wind tended to inhibit flying as well as affected the oviposition of mosquitoes or the placement of eggs in suitable positions and habitats. Increased wind speeds generally caused a decrease in the ability of mosquitoes flying with wind speeds of 1-4 m/s and it could inhibit the flight of mosquitoes.[18]

CONCLUSION

There are some useful information related to the DHF Cases. Analysis of the environmental factors such as precipitation, temperature, humidity and wind speed with the DHF cases has revealed that DHF generally occurred when average temperature rose above normal. The result of overlay of thematic annual precipitation and annual DHF cases map do not all have a directly proportional relationship spatially. In the time-series graph the monthly humidity relationship and monthly DHF cases tend to be reversed is the monthly DHF cases increase when the monthly humidity decreases.

The Multivariate analysis with *Poisson Regression* show that environment factor which influence DHF cases are DHF cases in in the previous month (*lag1*), monthly temperature in the same month (*lag0*), monthly temperature in the previous month (*lag1*), monthly humidity in the previous two months (*lag2*), and wind speed in the previous two months (*lag2*).

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